

# Astrophysics / Heliophysics (Including Space Weather)

## Teleoperation of Rovers on Planetary Surfaces

The Global Exploration Roadmap identified telepresence and teleoperation of rovers on planetary surfaces as important parts of the strategy for exploration of bodies in the solar system. In this talk, I will present a Telerobotics Roadmap that begins with simulations using rovers on the ground remotely controlled by astronauts in the ISS progressing to teleoperation of a rover on the lunar farside operated by Orion astronauts and leading to human orbital missions around Mars. The first space-based surface telerobotics engineering tests using the K-10 rover at the NASA Ames Roverscape under the command of astronauts aboard the ISS were conducted in the summer of 2013. During three 3.5-hr ISS crew sessions, Kapton film strips which will form the backbone of a low frequency radio antenna array were successfully unrolled from the back of the K-10 rover. These ISS crew sessions achieved a number of “firsts” including the first real-time teleoperation of a planetary rover from the ISS, the first astronaut to interactively control a high fidelity planetary rover in an outdoor analog testbed, and the first realistic simulation of a human-robot “Waypoint” mission concept. The next step in the Telerobotics Roadmap is at the Earth-Moon L2 libration point in the early 2020’s. This will provide an avenue to develop expertise needed for longer-duration missions in deep space and a platform to help discover answers to critical scientific questions concerning the origin of our solar system and the Universe’s first galaxies. Potential mission objectives include performing real-time telerobotic exploration on the lunar surface, operating a libration point outpost to practice operations needed for deep-space exploration, and establishing an “interplanetary gateway”, or assembly point for missions to more distant destinations. There are two primary science objectives for an “Orion L2 Farside Mission”. The first would be to return to Earth multiple rock samples from the Moon’s South Pole–Aitken (SPA) basin, one of the largest, deepest, and oldest impact basins in the solar system. A sample return from SPA was designated as a priority science objective in the National Research Council (NRC) Planetary Sciences Decadal Survey. The second objective would be to deploy a low radio frequency telescope, where it would be shielded from human-generated radio frequency interference from the Earth and free from ionospheric effects, allowing us to explore currently unobserved primitive epochs of the early Universe. Such observations were recently identified as one of the top science objectives in the NASA Astrophysics Roadmap.

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## A LUNAR LASER RANGING RETROREFLECTOR ARRAY FOR THE 21ST CENTURY: STATUS AND SIMULATIONS OF APOLLO ARRAYS AND FUTURE SCIENCE

Lunar Laser Ranging (LLR) to the Apollo Retroreflector arrays has produced detailed information concerning the crust and interior of the moon (e.g., the discovery 15 years ago of the liquid core). It has also produced some of the best tests of General Relativity (i.e., the Strong Equivalence Principal, the Inertial Properties of Gravitational Energy, the Constancy of the Gravitational Constant  $G$ , etc.). This analysis continues to the present. However, the combination of the design of the Apollo arrays and the lunar librations now limit the accuracy of the range measurements. Although the Apollo arrays are still operating and producing new science, Ground Stations (GSs) have improved their ranging accuracy by a factor of 200. As the moon liberates, the Apollo arrays of 100/300 Cube Corner Reflectors (CCRs) become tilted with respect to the GS. This means that a photon reflected from the far corner of the tilted panel has a greater measured range than a photon that is reflected from the near corner. Thus the path to new lunar physics, gravitational tests and General Relativity tests is a new generation of lunar retroreflectors. The "next generation" retroreflector package being developed [1] and technical challenges of these measurements to the Apollo array will be discussed. This project, the "Lunar Laser Ranging Retroreflector for the 21st Century" or LLRRA-21 [1] is centered at the University of Maryland and is being conducted within an international collaboration. Since the magnitude of the signal from the Apollo arrays has decreased, a detailed simulation [2] has been developed to identify the causes of the degradation in order to minimize their impact in the design of the LLRRA-21. The thermal/optical simulation is then compared to the observed returns from the Apollo arrays. It is especially helpful that the APOLLO station was able to obtain detailed observations during a lunar eclipse. During such an eclipse, the time constant of the changes of solar illumination is similar to the time constants of the CCRs and the array panel, thus providing critical new information for the simulation. Our nominal design is a system that will operate in both lunar day and night. This involves a sun shade and a pointing mechanism, the latter operating autonomously once shortly after launch. This system would weigh less than 3 kg. However, current rides have difficulty with this weight. As a result, we have investigated a non-shaded system that would mostly operate at lunar night. An analysis of this reduced schedule indicates that the loss of the science is minimal. Therefore for the first few rides, we expect to fly the system without sunshade nor pointing mechanism so the weight is less than a kilogram.

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## Measuring Cosmic Dawn from the Farside of the Moon – DARE approach

The lunar far side is shielded from the Earth-based radio frequency interference (RFI) and is free of the limiting ionospheric effects on Earth. Thus, it is a promising site for precision radio astronomical observations even from an orbit above the Moon, as concluded by the recent NASA Astrophysics Roadmap. The Dark Ages Radio Explorer (DARE) is designed to measure the redshifted, sky-averaged 21-cm signal which is perhaps the most promising near-term probe of the end of the Dark Ages and Cosmic Dawn, when the first stars and galaxies began to heat and ionize the Universe. Measurements are challenging, however, because of the intense foregrounds at the relevant low radio frequencies (40-120 MHz corresponding to redshifts  $z=11-35$ ) and the exquisite instrumental calibration this necessitates (1 ppm/ 106 dynamic range). DARE will orbit the Moon for a mission lifetime of 2 years and only take data above the lunar far side. Here, we outline the DARE mission, show the constraints it can place on the physics of the Cosmic Dawn, and demonstrate how the ionosphere puts a fundamental limit on the precision of similar, ground-based experiments. The DARE science instrument is composed of a three-element radiometer, including electrically-short, tapered, bi-conical dipole antennas, a receiver, and a digital spectrometer. Although the TRL (Technology Readiness Level) of the individual components of DARE instrument is high, the overall instrument TRL is low. One of the main aims of the entire DARE team is to advance the instrument TRL. Here, we present results from the latest engineering prototype which is deployed in Green Bank, WV, USA (a national radio-quiet zone). This research has been supported by the Lunar University Network for Astrophysics Research (LUNAR), headquartered at the University of Colorado Boulder and funded by the NASA Lunar Science Institute via Cooperative Agreement NNA09DB30A. Part of this research was conducted at the Jet Propulsion Laboratory, California Institute of Technology, under contract to the National Aeronautics and Space Administration.

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## Low Frequency Deployable Antennas for Space

The Jet Propulsion Laboratory (JPL) has been developing several deployable low frequency antenna concepts for use in space, particular in the lunar environment. These include antennas on spacecraft in lunar orbit and antennas for use on the lunar surface. In all cases the goal is to find low mass, low risk concepts for antennas that are physically large enough to be effective at frequencies below approximately 100 MHz. The primary scientific motivation for such antennas is observation of the highly redshifted spectral line of neutral hydrogen from the Dark Ages and Cosmic Dawn epochs, prior to the epoch of reionization. For some other scientific applications the relevant frequency range is below 10 MHz, corresponding to wavelength longer than 30 m. Recent results from JPL include prototype depolyable bi-conical dipole antenna for lunar orbiters, rover-deployed polyimide film antennas for the lunar surface, and inflation-driven film antennas for the lunar surface. Deployment and RF test results from all three concepts will be presented. Portions of this work have been supported by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration, and by the NASA Lunar Science Institute through the Lunar University Network for Astrophysics Research (LUNAR) collaboration.

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## Possible life detected on the planet Venus' surface

Possible life detected on the planet Venus' surface L.V.Ksanfomality, Space Research Institute, Moscow, Russia leksanf@gmail.com The position of the hypothetical habitability zone in extrasolar planetary system was considered by many authors. Approximately 1/4 of exoplanets orbit their stars at very low orbits, which leads to high temperatures of their surface (if any), up to 800 K or more. Some of them should have the physical conditions close to those of Venus. Is there any possibility that the life forms can exist at quite different environment than "normal", Earth-like physical settings? Namely the planet Venus could be the natural laboratory for studies of this type, having the dense, hot (735 K) oxygenless CO<sub>2</sub> - atmosphere and high, 9.2 MPa, pressure at the surface. It should be recalled that the only existing data of actual close in TV-observations of Venus' surface are the results of a series of missions of the Russian VENERA landers which took place the 1970s and 80s, working in the atmosphere and on the surface of Venus. No other results of this kind were obtained since. A re-examination of images of venusian surface obtained from the VENERA landers has been undertaken using a modern processing technique, with a view to detect any possible signs of life under the specific conditions on Venus. This speculative identification rests on two characteristics of these features: (a) their somewhat suggestive morphology and (b) their temporal appearance and behavior (present, than absent on subsequent images of the same area; or changing appearances). The re-examination has identified previously unreported features [1-4] that may correspond to hypothetical life forms on Venus' surface. Two of them, 'mushroom' (1) and 'amisada' similar to the Australian shingleback lizard in shape and size (2) are shown here. Analysis and comparison of the contents the sequence of panoramas of the venusian surface obtained in the course of the TV-experiments on the VENERA landers (1975-82), allowed the author to detect some interesting objects displayed on the panoramas. Following the change in their appearance on the sequence of images allowed a suggestion that such changes may be related to the possible habitability of the planet. Some of the objects found were described in few papers of L.Ksanfomality (2012). There are also found and listed in the report images of objects with special morphology resembling the shape of some terrestrial fauna. In the absence of new landing missions to Venus, the same study was carried out on the other remaining panoramas. There is a reason to believe that in the panoramas few class of unusual objects has been found, which will be shown in the report. References:[1] Ksanfomality L.V. 2013 Doklady Physics. 58 (5), 204[2] Ksanfomality L.V. 2013 Doklady Physics. 58 (11), 514[3] Ksanfomality L.V. 2013 International Journal of Astronomy and Astrophysics, 3, 57-79. [4] Ksanfomality L.V. 2014 International Journal of Astronomy and Astrophysics, 4, 29-38.

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## The Lunar Occultation Explorer

The Lunar Occultation Explorer (LOX) is a new  $\gamma$ -ray astrophysics mission concept being developed to enhance our knowledge of the Cosmos in the nuclear regime. LOX will orbit the Moon and use the Lunar Occultation Technique to address science goals that include a deep all-sky survey and continuous monitoring of nuclear transients, exploration of galactic nucleosynthesis and the life cycle of matter in our Galaxy, compact objects such as black holes, and key questions related to solar flare dynamics. We will present an overview of the mission concept, its capabilities and developmental progress, as well as review the breadth of LOX science objectives.

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## Surface Operations Concepts: A Rover Demonstration of Sample Acquisition and Radio Antenna Deployment

A lander carrying a rover has an expanded mission potential. For sample return missions, a rover enables the acquisition of a range of spatially distributed samples. For radio antenna deployment, most likely applicable to missions using the lunar surface as a platform for heliophysics or astrophysics observations, a rover enables the deployment of an array of antennas. We illustrate the surface operations portion of a mission concept that combines these two potential capabilities. The Axel rover system is a family of platforms designed to provide versatile mobility for scientific access and human-oriented exploration of planetary surfaces in the solar system. We equipped one of JPL's Axel rovers with a percussive drill and a deployment mechanism for rolls of metallized polyimide film. The drill had previously been demonstrated in acquiring powder samples from rocks, and the polyimide film had previously been demonstrated as a proof-of-concept radio antenna. The Axel rover was deployed in the JPL Mars Yard and operated remotely. Time delays of approximately 0.5 seconds were included in the operation of the rover—delays comparable to those likely to be experienced by astronauts in the cis-lunar environment tele-robotically operating a rover on the lunar surface and is only slightly shorter than traditional ground-based operation. In our surface operations demonstration, we illustrate the rover acquiring a powder sample, then deploying two radio antennas. We discuss "lessons learned" from this demonstration. Part of this research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with NASA.